Designation: D7012 – 14

Standard Test Methods for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures[1]

This standard is issued under the fixed designation D7012; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These four test methods cover the determination of the strength of intact rock core specimens in uniaxial and triaxial compression. Methods A and B determine the triaxial compressive strength at different pressures and Methods C and D determine the unconfined, uniaxial strength.

1.2 Methods A and B can be used to determine the angle of internal friction, angle of shearing resistance, and cohesion intercept.

1.3 Methods B and D specify the apparatus, instrumentation, and procedures for determining the stress-axial strain and the stress-lateral strain curves, as well as Young's modulus, *E*, and Poisson's ratio, υ. These methods make no provision for pore pressure measurements and specimens are undrained (platens are not vented). Thus, the strength values determined are in terms of total stress and are not corrected for pore pressures. These test methods do not include the procedures necessary to obtain a stress-strain curve beyond the ultimate strength.

1.4 Option A allows for testing at different temperatures and can be applied to any of the test methods, if requested.

1.5 This standard replaces and combines the following Standard Test Methods: D2664 Triaxial Compressive Strength of Undrained Rock Core Specimens Without Pore Pressure Measurements; D5407 Elastic Moduli of Undrained Rock Core Specimens in Triaxial Compression Without Pore Pressure Measurements; D2938 Unconfined Compressive Strength of Intact Rock Core Specimens; and D3148 Elastic Moduli of Intact Rock Core Specimens in Uniaxial Compression. The original four standards are now referred to as Methods in this standard.

1.5.1 *Method A:* Triaxial Compressive Strength of Undrained Rock Core Specimens Without Pore Pressure Measurements.

1.5.1.1 Method A is used for obtaining strength determinations. Strain is not typically measured; therefore a stress-strain curve is not produced.

1.5.2 *Method B:* Elastic Moduli of Undrained Rock Core Specimens in Triaxial Compression Without Pore Pressure Measurements.

1.5.3 *Method C:* Uniaxial Compressive Strength of Intact Rock Core Specimens.

1.5.3.1 Method C is used for obtaining strength determinations. Strain is not typically measured; therefore a stress-strain curve is not produced.

1.5.4 *Method D:* Elastic Moduli of Intact Rock Core Specimens in Uniaxial Compression.

1.5.5 *Option A: Temperature Variation*—Applies to any of the methods and allows for testing at temperatures above or below room temperature.

1.6 For an isotropic material in Test Methods B and D, the relation between the shear and bulk moduli and Young's modulus and Poisson's ratio are:

$$G = \frac{E}{2(1+\upsilon)} \tag{1}$$

$$K = \frac{E}{3(1-2\upsilon)} \tag{2}$$

where:

G = shear modulus,
K = bulk modulus,
E = Young's modulus, and
υ = Poisson's ratio.

1.6.1 The engineering applicability of these equations decreases with increasing anisotropy of the rock. It is desirable to conduct tests in the plane of foliation, cleavage or bedding and at right angles to it to determine the degree of anisotropy. It is noted that equations developed for isotropic materials may give only approximate calculated results if the difference in elastic moduli in two orthogonal directions is greater than 10 % for a given stress level.

NOTE 1—Elastic moduli measured by sonic methods (Test Method D2845) may often be employed as a preliminary measure of anisotropy.

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[1] These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.12 on Rock Mechanics.

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***A Summary of Changes section appears at the end of this standard**

1.7 Test Methods B and D for determining the elastic constants do not apply to rocks that undergo significant inelastic strains during the test, such as potash and salt. The elastic moduli for such rocks should be determined from unload-reload cycles that are not covered by these test methods.

1.8 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.9 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.9.1 The procedures used to specify how data are collected/recorded or calculated, in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analytical methods for engineering design.

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D2845 Test Method for Laboratory Determination of Pulse Velocities and Ultrasonic Elastic Constants of Rock

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D4543 Practices for Preparing Rock Core as Cylindrical Test Specimens and Verifying Conformance to Dimensional and Shape Tolerances

D6026 Practice for Using Significant Digits in Geotechnical Data

E4 Practices for Force Verification of Testing Machines

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

2.2 *ASTM Adjunct:*[3]

Triaxial Compression Chamber Drawings (3)

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms in this standard, refer to Terminology D653.

4. Summary of Test Method

4.1 A rock core specimen is cut to length and the ends are machined flat. The specimen is placed in a loading frame and if necessary, placed in a loading chamber and subjected to confining pressure. For a specimen tested at a different temperature, the test specimen is heated or cooled to the desired test temperature prior to the start of the test. The axial load on the specimen is then increased and measured continuously. Deformation measurements are not obtained for Methods A and C, and are measured as a function of load until peak load and failure are obtained for Methods B and D.

5. Significance and Use

5.1 The parameters obtained from Methods A and B are in terms of undrained total stress. However, there are some cases where either the rock type or the loading condition of the problem under consideration will require the effective stress or drained parameters be determined.

5.2 Method C, uniaxial compressive strength of rock is used in many design formulas and is sometimes used as an index property to select the appropriate excavation technique. Deformation and strength of rock are known to be functions of confining pressure. Method A, triaxial compression test, is commonly used to simulate the stress conditions under which most underground rock masses exist. The elastic constants (Methods B and D) are used to calculate the stress and deformation in rock structures.

5.3 The deformation and strength properties of rock cores measured in the laboratory usually do not accurately reflect large-scale *in situ* properties because the latter are strongly influenced by joints, faults, inhomogeneity, weakness planes, and other factors. Therefore, laboratory values for intact specimens must be employed with proper judgment in engineering applications.

NOTE 2—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing. Users of this standard are cautioned that compliance with Practice D3740 does not in itself ensure reliable results. Reliable results depend on many factors; Practice D3740 provides a means for evaluating some of those factors.

6. Apparatus

6.1 *Compression Apparatus:*

6.1.1 *Methods A to D:*

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Assembly and detail drawings of an apparatus that meets these requirements and which is designed to accommodate 54-mm diameter specimens and operate at a confining fluid pressure of 68.9 MPa are available from ASTM International Headquarters. Order Adjunct No. ADJD7012. Original adjunct produced in 1982.

6.1.1.1 *Loading Device*—The loading device shall be of sufficient capacity to apply load at a rate conforming to the requirements specified in 9.4.1. It shall be verified at suitable time intervals in accordance with the procedures given in Practices E4 and comply with the requirements prescribed in the method. The loading device may be equipped with a displacement transducer that can be used to advance the loading ram at a specified rate.

NOTE 3—For Methods A and B, if the load-measuring device is located outside the confining compression apparatus, calibrations to determine the seal friction need to be made to make sure the loads measured meet the accuracy specified in Practices E4.

6.2 *Confining System:*[3]

6.2.1 *Methods A and B:*

6.2.1.1 *Confining Apparatus*[4]—The confining pressure apparatus shall consist of a chamber in which the test specimen may be subjected to a constant lateral fluid pressure and the required axial load. The apparatus shall have safety valves, suitable entry ports for filling the chamber, and associated hoses, gages, and valves as needed.

6.2.1.2 *Flexible Membrane*—This membrane encloses the rock specimen and extends over the platens to prevent penetration by the confining fluid. A sleeve of natural or synthetic rubber or plastic is satisfactory for room temperature tests; however, metal or high-temperature rubber (viton) jackets are usually necessary for elevated temperature tests. The membrane shall be inert relative to the confining fluid and shall cover small pores in the specimen without rupturing when confining pressure is applied. Plastic or silicone rubber coatings may be applied directly to the specimen provided these materials do not penetrate and strengthen or weaken the specimen. Care must be taken to form an effective seal where the platen and specimen meet. Membranes formed by coatings shall be subject to the same performance requirements as elastic sleeve membranes.

6.2.1.3 *Pressure-Maintaining Device*—A hydraulic pump, pressure intensifier, or other system having sufficient capacity to maintain the desired lateral pressure to within ±1 % throughout the test. The confining pressure shall be measured with a hydraulic pressure gauge or electronic transducer having an accuracy of at least ±1 % of the confining pressure, including errors due to readout equipment, and a resolution of at least 0.5 % of the confining pressure.

6.2.1.4 *Confining-Pressure Fluids*—Hydraulic fluids compatible with the pressure-maintaining device and flexible membranes shall be used. For tests using Option A, the fluid must remain stable at the temperature and pressure levels designated for the test.

6.2.2 *Option A:*

6.2.2.1 *Temperature Enclosure*—The temperature enclosure shall be either an internal system that fits inside the loading apparatus or the confining pressure apparatus, an external system enclosing the entire confining pressure apparatus, or an external system encompassing the complete test apparatus. For high or low temperatures, a system of heaters or coolers, respectively, insulation, and temperature-measuring devices are normally necessary to maintain the specified temperature. Temperature shall be measured at three locations, with one sensor near the top, one at mid-height, and one near the bottom of the specimen. The "average" specimen temperature, based on the mid-height sensor, shall be maintained to within ±1°C of the specified test temperature. The maximum temperature difference between the mid-height sensor and either end sensor shall not exceed 3°C.

NOTE 4—An alternative to measuring the temperature at three locations along the specimen during the test is to determine the temperature distribution in a specimen that has temperature sensors located in drill holes at a minimum of six positions: along both the centerline and specimen periphery at mid-height and each end of the specimen. The specimen may originate from the same batch as the test specimens and conform to the same dimensional tolerances and to the same degree of intactness. The temperature controller set point may be adjusted to obtain steady-state temperatures in the specimen that meet the temperature requirements at each test temperature. The centerline temperature at mid-height may be within ±1°C of the specified test temperature and all other specimen temperatures may not deviate from this temperature by more than 3°C. The relationship between controller set point and specimen temperature can be used to determine the specimen temperature during testing provided that the output of the temperature feedback sensor or other fixed-location temperature sensor in the triaxial apparatus is maintained constant within ±1°C of the specified test temperature. The relationship between temperature controller set point and steady-state specimen temperature may be verified periodically. The specimen is used solely to determine the temperature distribution in a specimen in the triaxial apparatus. It is not to be used to determine compressive strength or elastic constants.

6.2.2.2 *Temperature Measuring Device*—Special limits-of-error thermocouples or platinum resistance thermometers (RTDs) having accuracies of at least ±1°C with a resolution of 0.1°C shall be used.

6.2.3 *Bearing Surfaces:*

6.2.3.1 *Methods A to D:*

(1) Platens—Two steel platens are used to transmit the axial load to the ends of the specimen. They shall be made of tool-hardened steel to a minimum Rockwell Hardness of 58 on the "C" scale. One of the platens shall be spherically seated and the other shall be a plain rigid platen. The bearing faces shall not depart from a plane by more than 0.015 mm when the platens are new and shall be maintained within a permissible variation of 0.025 mm. The diameter of the spherical seat shall be at least as large as that of the test specimen, but shall not exceed twice the diameter of the test specimen. The center of the sphere in the spherical seat shall coincide with that of the bearing face of the specimen. The spherical seat shall be properly lubricated to allow free movement. The movable portion of the platen shall be held closely in the spherical seat, but the design shall be such that the bearing face can be rotated and tilted through small angles in any direction. If a spherical seat is not used, the bearing surfaces shall be parallel to 0.0005 mm/mm of platen diameter. The platen diameter shall be at least as great as that of the specimen and have a thickness-to-diameter ratio of at least 1:2.

6.3 *Deformation Devices:*

6.3.1 *Methods B and D:*

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[4] Assembly and detail drawings of an apparatus that meets these requirements and which is designed to accommodate 21/8-in. (53.975-mm) diameter specimens and operate at a confining fluid pressure of 68.9 MPa are available from ASTM International Headquarters. Order Adjunct No. ADJD7012. Original adjunct produced in 1982.

6.3.1.1 *Strain/Deformation Measuring Devices*—Deformations or strains may be determined from data obtained by electrical resistance strain gages, compressometers, linear variable differential transformers (LVDTs), or other suitable means. The strain/deformation measuring system shall measure the strain with a resolution of at least 25×10^{-6} strain and an accuracy within 2 % of the value of readings above 250×10^{-6} strain and accuracy and resolution within 5×10^{-6} for readings lower than 250×10^{-6} strain, including errors introduced by excitation and readout equipment. The system shall be free from non-characterized long-term instability (drift) that results in an apparent strain of 10^{-8}/s or greater.

NOTE 5—The user is cautioned about the influence of pressure and temperature on the output of strain and deformation sensors located within the confining pressure apparatus.

6.3.1.2 *Determination of Axial Strain*—The design of the measuring device shall be such that the average of at least two axial strain measurements can be determined. Measuring positions shall be equally spaced around the circumference of the specimen, close to midheight. The gauge length over which the axial strains are determined shall be at least ten grain diameters in magnitude.

6.3.1.3 *Determination of Lateral Strain*—The lateral deformations or strains may be measured by any of the methods mentioned in 6.3.1.1. Either circumferential or diametric deformations or strains may be measured. A single transducer that wraps around the specimen can be used to measure the change in circumference. At least two diametric deformation sensors shall be used if diametric deformations are measured. These sensors shall be equally spaced around the circumference of the specimen close to midheight. The average deformation or strain from the diametric sensors shall be recorded.

NOTE 6—The use of strain gauge adhesives requiring cure temperatures above 65°C is not allowed unless it is known that microfractures do not develop and mineralogical changes do not occur at the cure temperature.

6.4 *Timing Devices*—A clock, stopwatch, digital timer, or alike readable to 1 minute.

7. Safety Precautions

7.1 Danger exists near confining pressure testing equipment because of the high pressures and loads developed within the system. Test systems must be designed and constructed with adequate safety factors, assembled with properly rated fittings, and provided with protective shields to protect people in the area from unexpected system failure. The use of a gas as the confining pressure fluid introduces potential for extreme violence in the event of a system failure.

7.2 Many rock types fail in a violent manner when loaded to failure in compression. A protective shield shall be placed around the uniaxial test specimen to prevent injury from flying rock fragments.

7.3 Elevated temperatures increase the risks of electrical shorts and fire. The flash point of the confining pressure fluid shall be above the operating temperatures during the test.

8. Test Specimens

8.1 *Specimen Selection*—The specimens for each sample shall be selected from cores representing a valid average of the type of rock under consideration. This sample selection can be achieved by visual observations of mineral constituents, grain sizes and shape, partings and defects such as pores and fissures, or by other methods such as ultrasonic velocity measurements. The diameter of rock test specimens shall be at least ten times the diameter of the largest mineral grain. For weak rock types, which behave more like soil, for example, weakly cemented sandstone, the specimen diameter shall be at least six times the maximum particle diameter. The specified minimum specimen diameter of approximately 47-mm satisfy this criterion in the majority of cases. When cores of diameter smaller than the specified minimum must be tested because of the unavailability of larger diameter core, as is often the case in the mining industry, suitable notation of this fact shall be made in the report.

8.1.1 Desirable specimen length to diameter ratios are between 2.0:1 and 2.5:1. Specimen length to diameter ratios of less than 2.0:1 are unacceptable. If it is necessary to test specimens not meeting the length to diameter ratio requirements due to lack of available specimens, the report shall contain a note stating the non-conformance with this standard including a statement explaining that the results may differ from results obtained from a test specimen that meets the requirements. Laboratory specimen length to diameter ratios must be employed with proper judgment in engineering applications.

8.1.2 The number of specimens necessary to obtain a specific level of statistical results may be determined using Test Method E122. However, it may not be economically possible to achieve a specific confidence level and professional judgment may be necessary.

8.2 *Preparation*—Test specimens shall be prepared in accordance with Practice D4543.

8.2.1 Test results for specimens not meeting the requirements of Practice D4543 shall contain a note describing the non-conformance and a statement explaining that the results reported may differ from results obtained from a test specimen that meets the requirements of Practice D4543.

8.3 Moisture condition of the specimen at the time of test can have a significant effect upon the deformation of the rock. Good practice generally dictates that laboratory tests shall be made upon specimens representative of field conditions. Thus, it follows that the field moisture condition of the specimen shall be preserved until the time of test. On the other hand, there may be reasons for testing specimens at other moisture contents, including zero. In any case, the moisture content of the test specimen shall be tailored to the problem at hand and determined according to the procedures given in Method D2216. If moisture condition is to be maintained and the temperature enclosure is not equipped with humidity control, the specimen shall be sealed using a flexible membrane or by applying a plastic or silicone rubber coating to the specimen sides. If the specimen is to be saturated, porous sandstones may present little or no difficulty. For siltstone, saturation may take longer. For tight rocks such as intact granite, saturation by water may be impractical.